ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Report On

PROJECT No. 28 - Investigation of the Hazard from Exhaust Gases in Tanks that are in Tow

Subject: Carbon Monoxide Hazard From Gases In Tanks That Are In Tow

INFORMATION COPY

Action copies have been forwarded to Requirements Section, AGF for approval and execution.

Project No. 28

11 May 1944

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 28
723.13-1 SPMEA

11 May 1944

CARBON MONOXIDE HAZARD FROM EXHAUST GASES IN TANKS THAT ARE IN TOW

1. PROJECT: No. 28, Investigation of the Hazard from Exhaust Gases in Tanks that are in Tow.

a. Authority - 5th Indorsement, Commanding General, Army Ground Forces, 451.12 (27 Dec 43) GNRQT - 4/72264.

b. Purpose - To investigate the magnitude of the carbon monoxide hazard in a towed tank resulting from pollution by the engine exhaust of the towing vehicle.

2. DISCUSSION:

a. This report covers the investigation of the carbon monoxide hazard in tanks being towed by each of four towing vehicles; M4A1 and M4A3 medium tanks, and M32B1 and M32B3, recovery vehicles, over two courses representing level road and upgrade driving, the tanks each being tested alternately with towing bar and towing cable.

b. Carbon monoxide concentrations were determined at several positions in the towed vehicle; driver, assistant driver, loader and commander (breathing level when out of turret hatch). Measurements were made with a Mine Safety Appliance Carbon Monoxide Indicator.

c. Wind velocity and direction relative to tank direction was measured during all trials.

d. Simple modifications were made to divert the path of exhaust gases in instances where high concentrations were produced.

e. Results are presented in detail in the appendix.

3. CONCLUSIONS:

a. M4A1 Medium Tank -

(1) Standard operation of this tank as a towing vehicle produces a dangerous carbon monoxide hazard for all occupants of the towed vehicle when the Bar, tow, is utilized as a connector. (See Fig. 1 & 3)

(2) Standard operation of this tank as a towing vehicle does not produce a hazardous situation for occupants of towed vehicle when the cable, tow, is utilized as a connector. (See Fig. 2).

(3) A simple exhaust deflector plate results in a reduction of the carbon monoxide exposure of the occupants of the towed tank to tolerable levels when the tow bar is used. See Fig. 10, Appendix.

b. M4A3 Medium Tank -

(1) Standard operation of the Tank as a towing vehicle does not produce hazardous conditions for occupants of the towed tank when either the Bar, tow (see Fig. 4) or Cable, tow (see Fig. 5) is used as a connector.

c. M32B1 Recovery Vehicle -

(1) Standard operation of this vehicle as a towing vehicle produces a seriously dangerous carbon monoxide hazard for any occupants of the towed tank when the Bar, tow is utilized as a connector. (See Figs. 6 & 7).

(2) Operation with an exhaust deflector plate reduces the exposure to levels within acceptable limits of operation. (See Figs. 6 & 7).

d. M32B3 Recovery Vehicle -

(1) Standard operation of this towing vehicle does not produce a hazardous situation for occupants of the towed vehicle when the Bar, tow is utilized as a connector. (See Figs. 7,8 & 9).

4. RECOMMENDATIONS:

a. That Ordnance develop a suitable device to eliminate the exhaust fume hazard from M32B1 recovery vehicle, and that this be submitted for test.

b. That all crews of recovery vehicles and tanks be informed of the potential danger of carbon monoxide poisoning in towed tanks and that instructions be issued to keep men out of tanks in tow so far as possible. This applies particularly to the use of the M4A1 medium tank and M32B1

recovery vehicle with Bar,tow, as connector, and that frequent periodic check of the occupants of the towed vehicle be made.

(NOTE: The conclusions and recommendations set forth above have been concurred in by Headquarters, Armored Center, W.H. Nutter, Colonel, G.S.C., Chief of Staff)

Submitted by:

Norton Nelson, Major, SnC
Robert H. Walpole, Capt. F. A.
T. C. Swigert, M/Sgt.

APPROVED Willard Machle
WILLARD MACHLE
Colonel, Medical Corps,
Commanding.

2 Incls.
#1 - Appendix
#2 - Figs. 1 thru 10

APPENDIX

A. The extent of the carbon monoxide hazard likely to be encountered by occupants of towed vehicles is dependent on a number of factors--some of which are predictable, some highly variable and erratic. These factors include:

(1) Design of exhaust discharge. In the M4A1 the exhaust discharges directly to the rear and surrounds the following tank with, under certain conditions, only minor dilution of the exhaust gases. Consequently, there is a serious danger of exposing occupants of the towed tank to high concentrations of carbon monoxide. The M4A3 exhaust on the other hand is diverted and diluted and is a much less serious source of carbon monoxide from this standpoint.

(2) Distance between towing and towed vehicles. The hazard in the towed vehicle is determined primarily by extent of dilution of the exhaust gases before reaching it. Consequently, use of the towing cable greatly reduces the potential hazard as compared with the situation when the towing bar is employed.

(3) Volume discharge of carbon monoxide. Heavy pulling increases the volume of exhaust gas discharged and tends to increase the potential carbon monoxide hazard.

(4) The effect of wind movement. This is apt to be highly variable, but in general low air movement (as in a ravine, close growth, or during heavy muggy weather) increases the danger.

B. The unbaffled exhaust terminals on tanks and recovery vehicles (M4A1 medium tank and M32B1 Recovery Vehicle) powered with radial engines, are mainly responsible for the high degree of carbon monoxide contamination in a towed tank. When a tow bar is used as a connector the distance is insufficient to insure adequate dilution of the exhaust gases before reaching the towed vehicle. On the M4A3 medium tank and the M32B3 Recovery vehicle, the exhaust port design, which is combined with the engine cooling air discharge deflector, insures a satisfactory degree of dilution of the carbon monoxide.

To eliminate the hazard from radial engine vehicles the most effective solution would be to establish a mandatory rule that there be no occupants in any towed vehicle. In combat zones this may not be possible because the crew must remain within their tank for protection until removed from the zone of fire. This distance may be short or it may be long with a potentially dangerous result. The quick-hitch connector now under development may require the presence of a driver in the towed vehicle for guiding purposes. Thus, such a mandatory rule is impractical, and a means of protection must be provided for this individual.

A second means of control is the application of an exhaust deflector plate, installed over the exhaust ports. This diverts the exhaust gases down-

Incl. #1

ward and the same time insures mixture and dilution with the engine cooling air. A metal sheet 30" wide by 24" deep, extending beyond the exhaust port on both sides was installed on both the M4A1 and M32B1 vehicles with satisfactory results. (see Fig. 10). Such a modification can be made at a first echelon maintenance station. This plate, in addition to minimizing the carbon monoxide hazard, may also eliminate exhaust flash identification during night operations. This, or an equal effective modification should be applied permanently to all M32B1 vehicles and should be installed on all M4A1 medium tanks which have a towing bar included in their storage items.

Figs. 1 thru 9 show the maximum carbon monoxide concentration measured during the series of trials. Wind direction and velocity cause some variation in concentration but the results may be taken as representative of the levels which may be expected. In the trial on the M32B1 it was necessary for the turret occupants of the towed vehicle to wear a gas mask with all purpose cannister (carbon monoxide) in order to continue the test.

The time-concentration curves for CO with the M4A1 tank as the towing vehicle are shown in Figs. 1 and 3. The average concentration at the driver's position for the 2[illegible] minute trial was 0.13[illegible], Fig. 1. A comparison of results of towing with and without the exhaust deflector plate over an identical course with approximately the same wind velocity and direction is shown on Fig. 3. In contrast to the serious condition resulting from the standard operation, use of the deflector plate brings the concentration well below acceptable limits.

Figs. 2,4,5,8 and 9 illustrate operation of the M4A3 medium tank, and the M32B3 with towing bar and towing cables. All trials indicate tolerable conditions in the towed vehicle.

In Figs. 6 & 7, conditions resulting from operation of the standard M32B1 recovery vehicle and with the baffle plate installed are compared for two types of driving courses. The average carbon monoxide concentration at the driver's position was 0.14[illegible] (Fig. 6). Under standard conditions of operation the use of deflector plate, however, reduced the concentration well below the allowable limit. Fig. 7 illustrates similar comparative results on trials over a flat road surface.

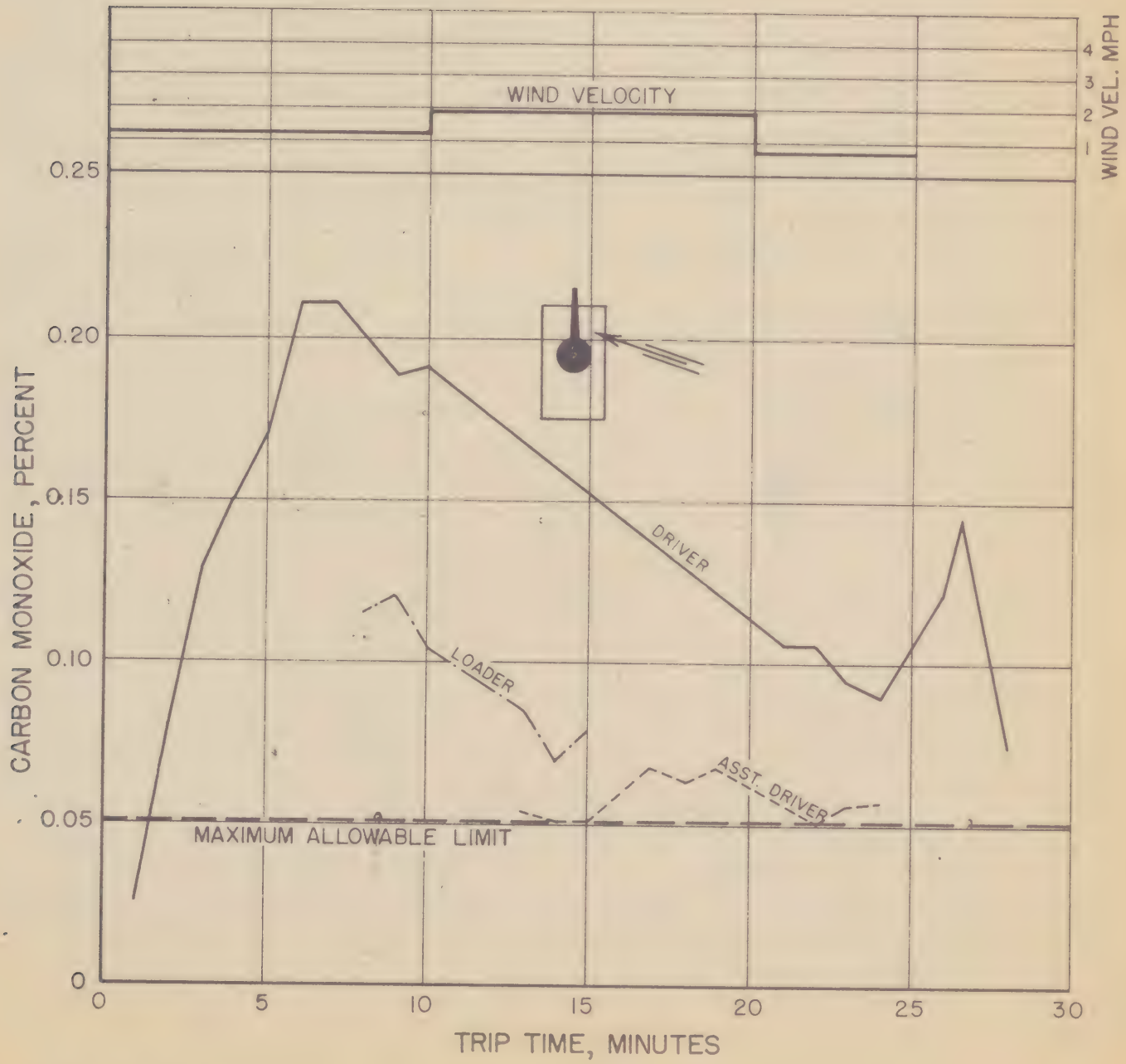
Appendix

Incl. #1

FIG. 1

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M4A1 MEDIUM TANK ON ROAD COURSE - 4 % GRADE

WITH TOWING BAR



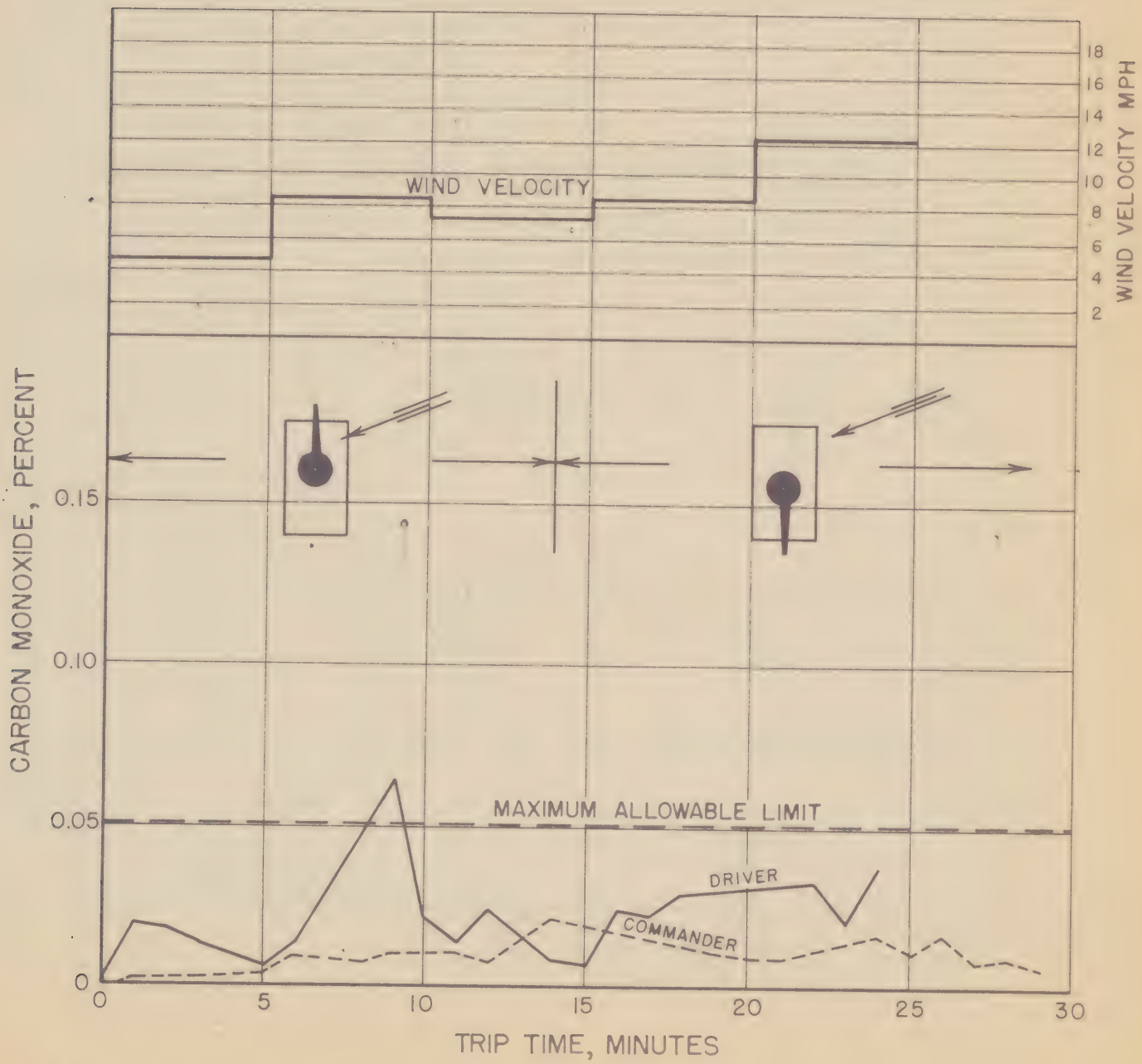
Trial #2

FIG. 1

FIG. 2

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M4A1 MEDIUM TANK ON FLAT ROAD SURFACE

WITH TOWING CABLE



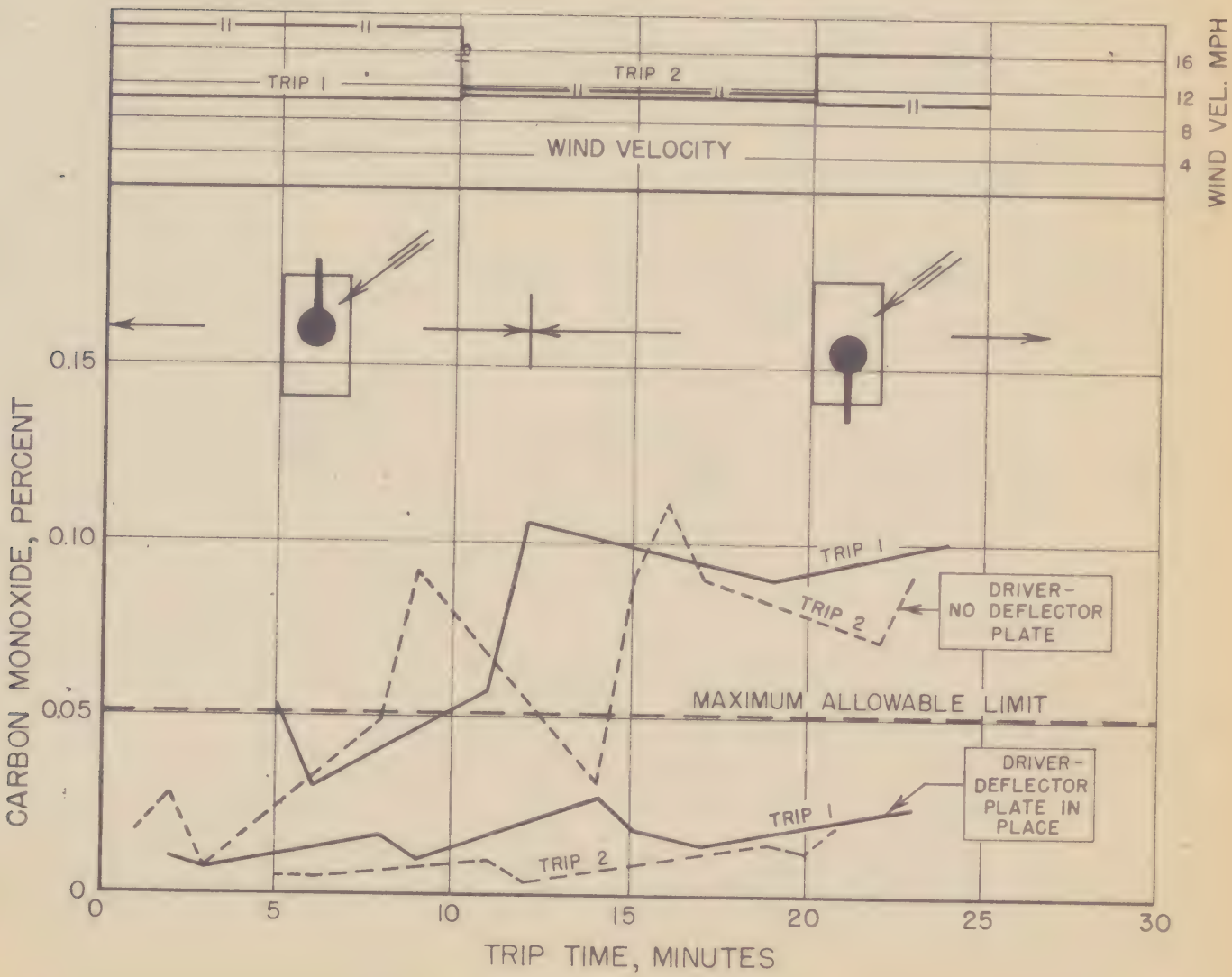
Sheet # 2

FIG. 2

FIG. 3

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M4A1 MEDIUM TANK ON FLAT ROAD SURFACE

WITH TOWING BAR



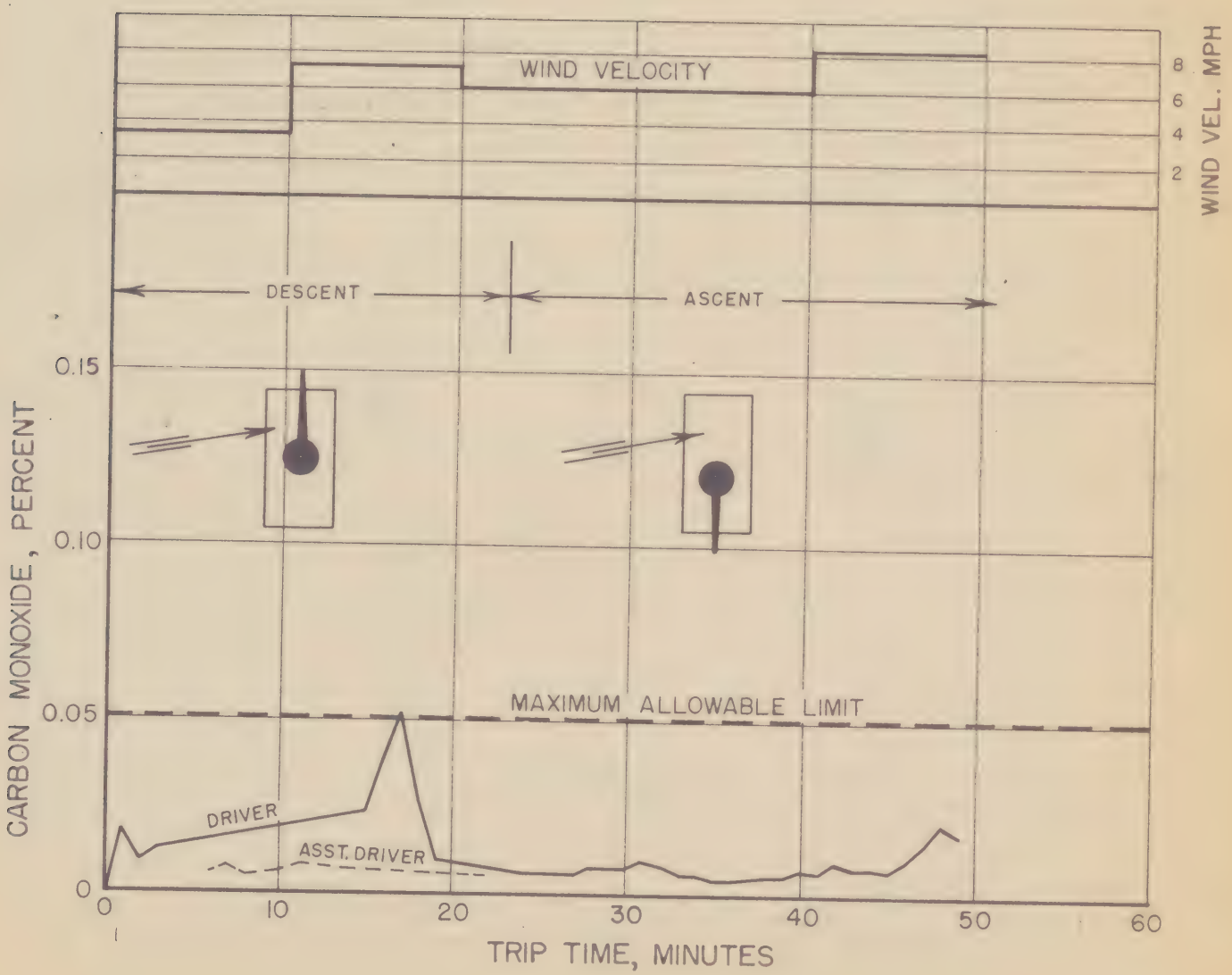
Incl 11 2

FIG. 3

FIG. 4

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M4A3 MEDIUM TANK ON ROAD COURSE – 4 % GRADE

WITH TOWING BAR



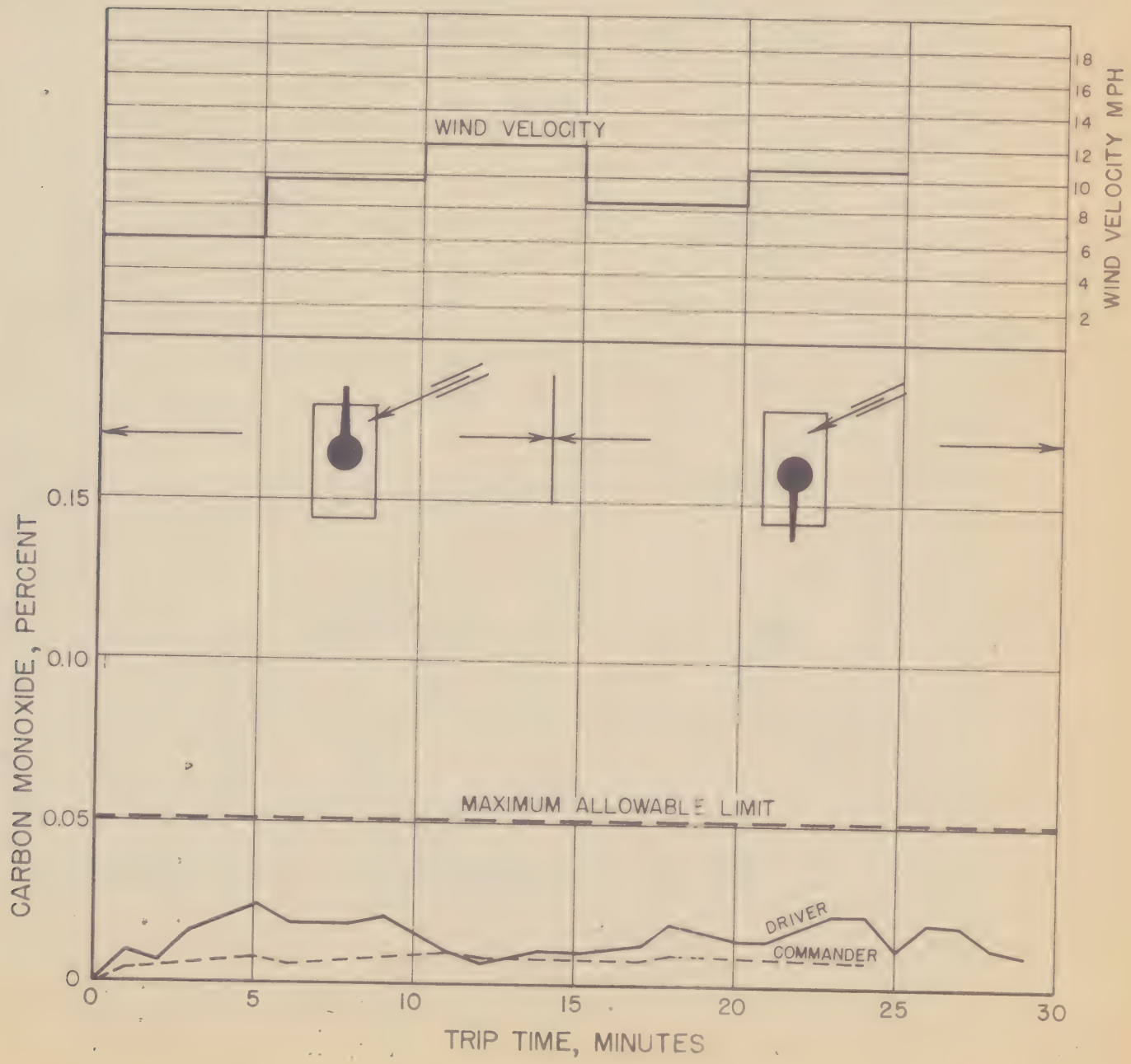
Sheet # 2

FIG. 4

FIG. 5

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M4A3 MEDIUM TANK ON FLAT ROAD SURFACE

WITH TOWING CABLE



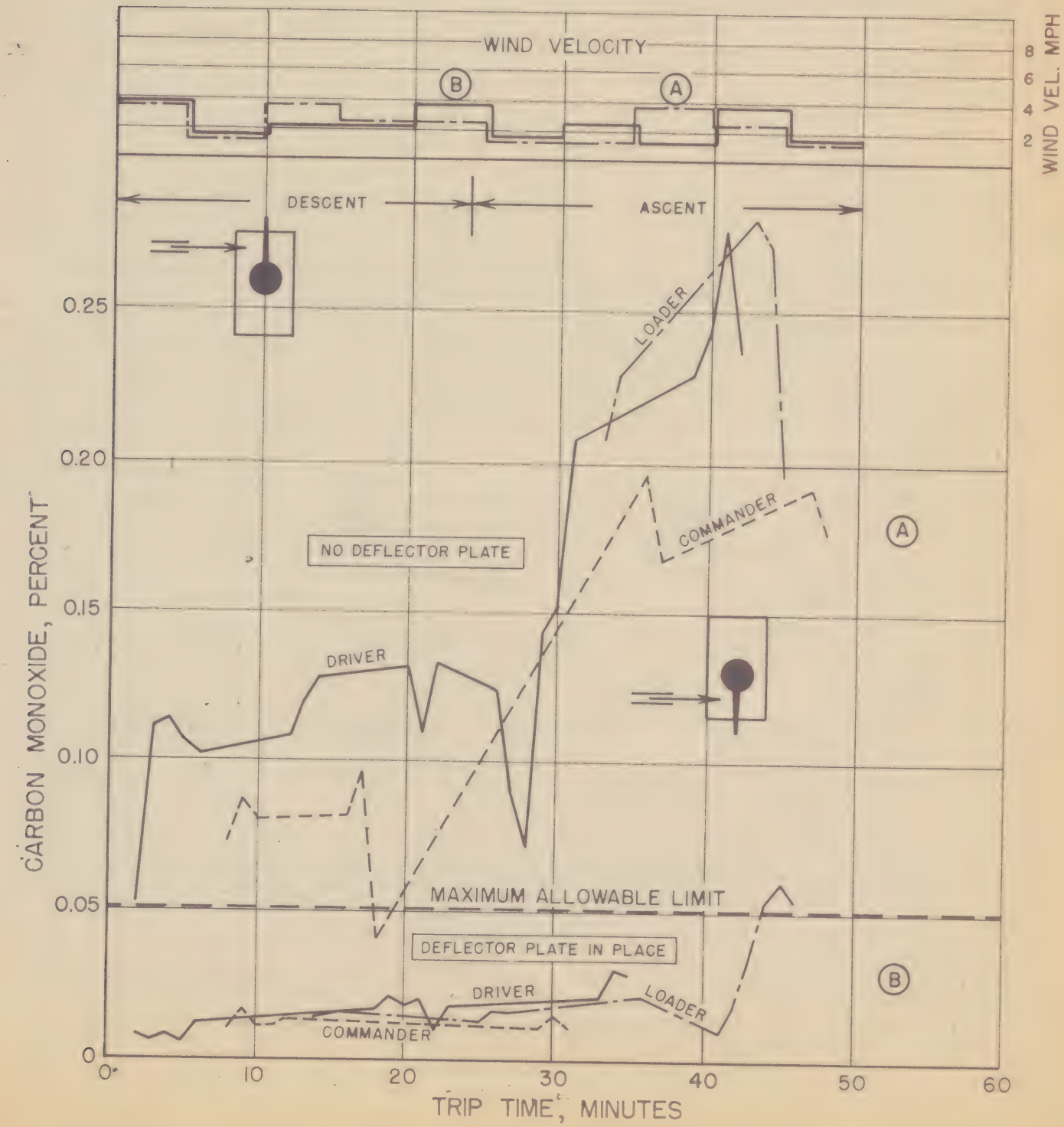
Ind #2

FIG. 5

FIG. 6

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M32B1 RECOVERY VEHICLE ON ROAD COURSE OF 4.0 % GRADE

WITH TOWING BAR



Inel #2

FIG. 6

FIG. 7

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M32B1 RECOVERY VEHICLE ON FLAT ROAD SURFACE

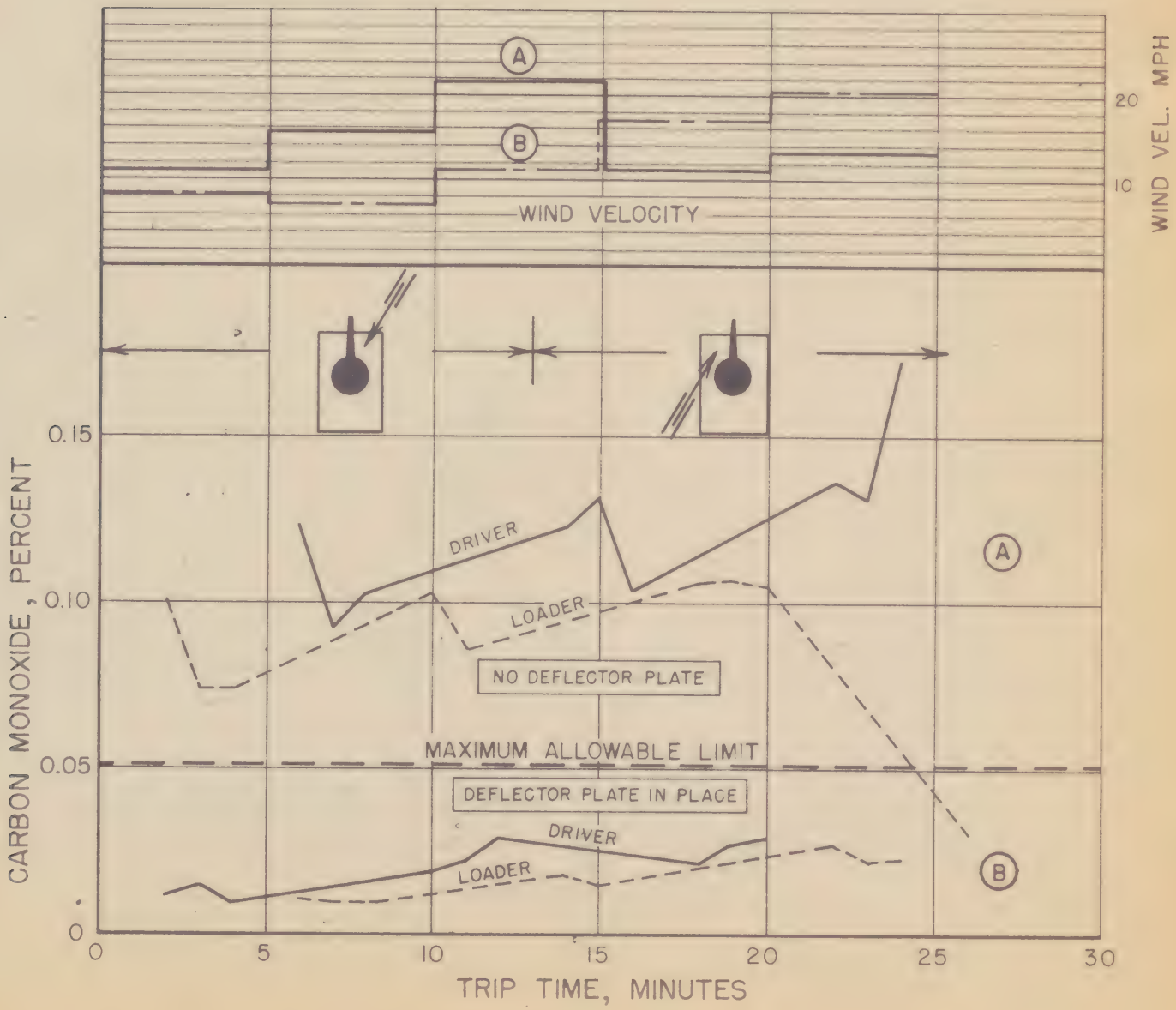
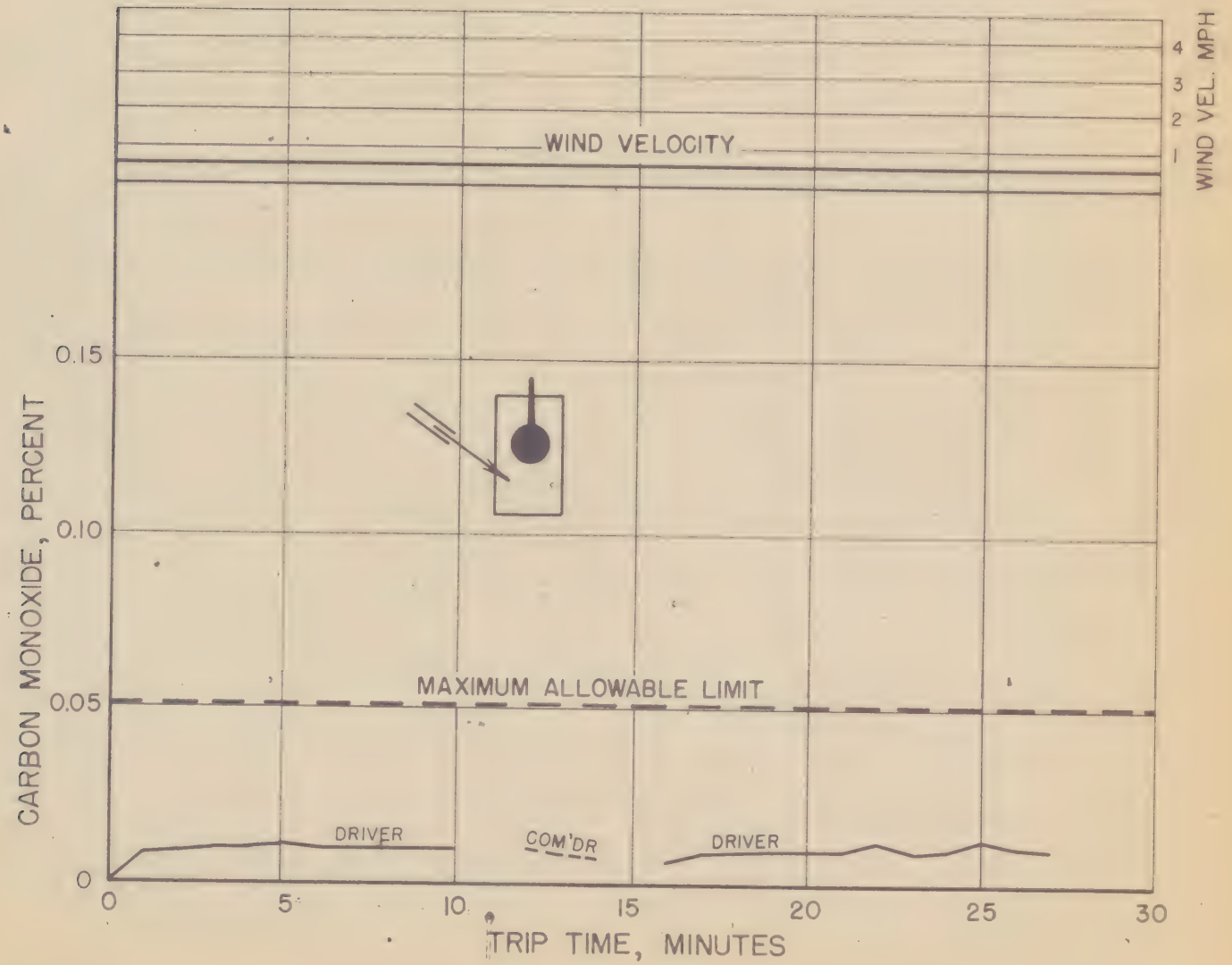


FIG. 7

FIG. 8

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M32B3 RECOVERY VEHICLE ON FLAT ROAD SURFACE

WITH TOWING BAR



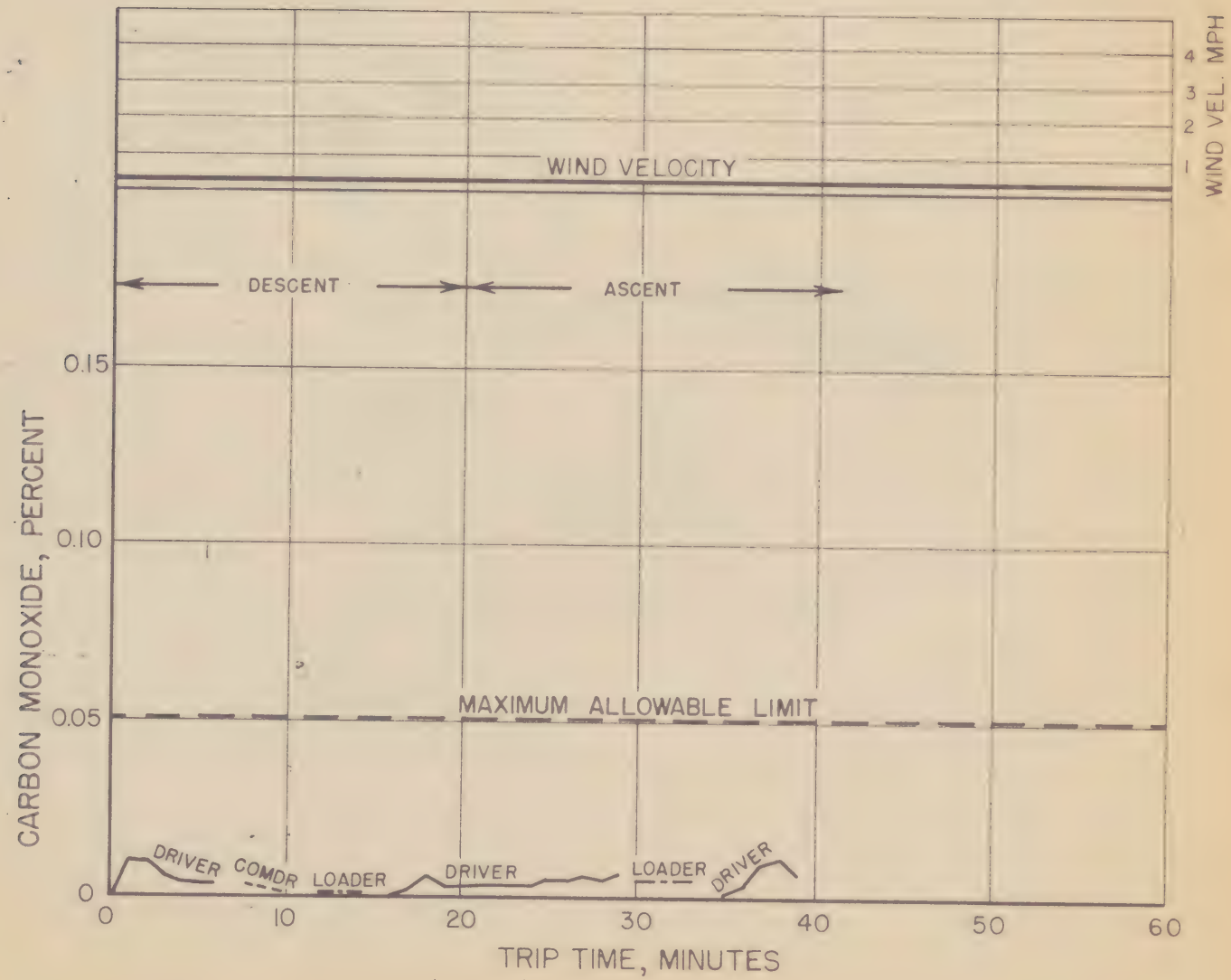
Incl No 2

FIG. 8

FIG. 9

CARBON MONOXIDE CONCENTRATIONS IN MEDIUM TANK TOWED BY M32B3 RECOVERY VEHICLE ON ROAD COURSE OF 4 % GRADE

WITH TOWING BAR

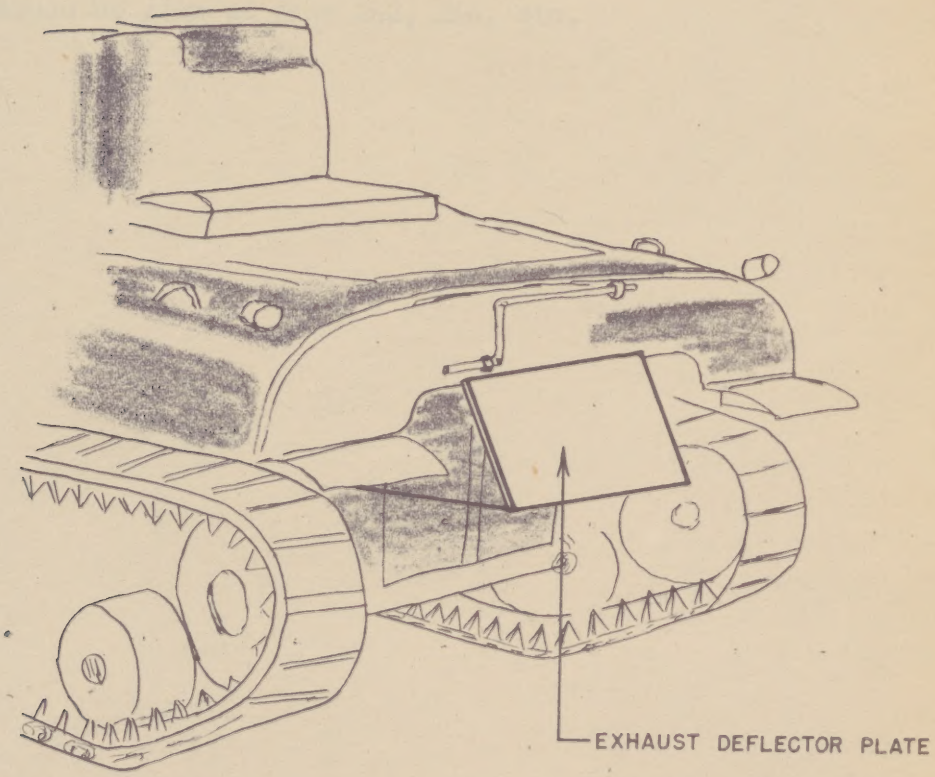


Sheet # 2

FIG. 9

FIG. 10

LOCATION OF EXHAUST DEFLECTOR PLATE FOR M4A1 MEDIUM TANK AND M32B1 RECOVERY VEHICLE



Fuel # 2

FIG. 10

CORRIGENDA

Page 16, Sect. 10, paragraph 4, line 3: after the words "were used" insert "(2) ratings of acceptability good, fair or poor, (3) quantity consumed and (4)".

Page 135, data for Y Company, inadvertantly omitted from this figure, may be found in table 1,a on page 129.

Page 152, Sect. 7, paragraph 1, line 6, after the words "inadequacy of" insert "the rations. Such variations are the result of such conditions of the study as the" following etc.

Page 240 - should be same as page 242, 244, etc.